

STUDY REPORT

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The Bracing Performance of Long Plasterboard-Lined Walls

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Preface

This report was prepared to detail testing undertaken to determine the bracing performance of long plasterboard-lined walls.

Acknowledgments

This work was funded by the Building Research Levy.

Note

This report is intended for researchers investigating bracing test methods and house performance in earthquakes.

The Bracing Performance of Long Plasterboard-Lined Walls

BRANZ Study Report SR 273

SJ Thurston

Reference

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Abstract

Theoretical calculation and racking test results showed a brittle response for long but isolated bracing walls. However, experimental tests of long walls when incorporated in a building with trims such as scotias and skirtings, showed they had a more ductile response with a strength approximately twice that of combined isolated walls of the same total length.

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1. INTRODUCTION

This project investigated the bracing performance of long plasterboard walls and compared this with predictions of bracing strength from published unit bracing ratings established in P21 [1] testing. Racking tests were performed on a small building in which the horizontal bracing in one direction was provided by a 2.4 m and 3.6 m long plasterboard wall on each of the two exterior walls. The test building had been constructed for another project involving bracing tests but before demolition the building frame was modified for use in this project.

2. BACKGROUND

P21 racking tests on long, isolated, plasterboard-lined walls at BRANZ in both confidential commercial work and research [2] work and elsewhere [3] found that they exhibited a brittle performance and that the resisted load fell off dramatically at approximately 20 mm of wall top plate deflection. This observation matched the theory discussed in the next paragraph.

It has been well established that, where wall rocking is prevented, the racking load-deflection performance of sheet-lined walls can be accurately predicted from the relationship between fastener shear load and the slip between sheet and framing, called e_n . The shear wall formula in NZS 3603 [4] is effectively based on the same theory and relates the wall horizontal deflection to e_n of the panel corner fasteners. Appendix A uses this formula to show that for the same wall deflection, the corner fasteners of long walls have far greater values of e_n than for short walls. Thus, more distress occurs at these fasteners and because of this their load resisting capability diminishes quickly, unzipping occurs and the total wall performance is consequently brittle.

3. TEST HOUSE DESCRIPTION

The test building was a single-room, single-storey building construction shown in Figure 1. It had plasterboard-lined light timber-framed (LTF) walls, a timber-framed plasterboard-lined ceiling with a 20 mm thick particle board floor on top. It was nominally 2.4 m high and incorporated 2.4 m and 3.6 m long plasterboard bracing elements on each of the two exterior walls. These were separated by a 0.4 m long full-height opening.

A total of 2220 kg of weights was added to the roof. If the building is intended to simulate an 8 m wide house then this represents an average roof weight of $2220/8/6.49 = 42.7 \text{ kg/m}^2$. Note that NZS 3604 [5] assumes a heavy roof weighs 20–60 kg/m^2 .

Construction complied with NZS 3604 and with the Gib® site guide [6]. The walls were lined with 10 mm standard plasterboard fixed as per the Gib® EzyBrace 2011 [6] fastener pattern with 32 mm drywall screws. The pattern entailed screws placed at 150 mm centres around the perimeter of the bracing elements, with the screw density increased at the corner of each bracing element. (Screws were placed at 50, 100, 150, 225 and 300 mm on horizontal and vertical sheet edges from each corner.) Sheets were also screwed at 300 mm centres along intermediate studs. They were not glued to the framing. Other construction details are listed below:

- Gib® Handibracs [6] were used on the studs at the ends of the bracing panels. The Handibracs were coach-screwed to the foundation beam and incorporated the Tek screws that were provided with the Handibrac. The bottom plates of the walls were also bolted or coach-screwed to the foundation beam at a maximum of 1.4 m centres.

- 50 mm wide timber skirting was nailed with 60 x 2.8 mm brads at approximately 300 mm centres over the lining at the base of all walls.
- A 10 mm gap was used at the bottom of the lining as per Page 32 of the Gib® site guide.
- The plasterboard edges on the ends of bracing panels, which were not at the building corners, finished flush with the ends of the panels and the edges had architraves and planted stops on them.

Side 1 and End 1 used 75 mm Gib Scotia along wall/ceiling junctions whereas Side 2 and End 2 used nailed timber scotias along the wall/ceiling junction.

4. TEST REGIME

The ceiling was horizontally displaced using an actuator which moved a load beam connected to the particle board flooring as shown in Figure 1. The load rate was sinusoidal with respect to time with an average speed of 4 mm/s.

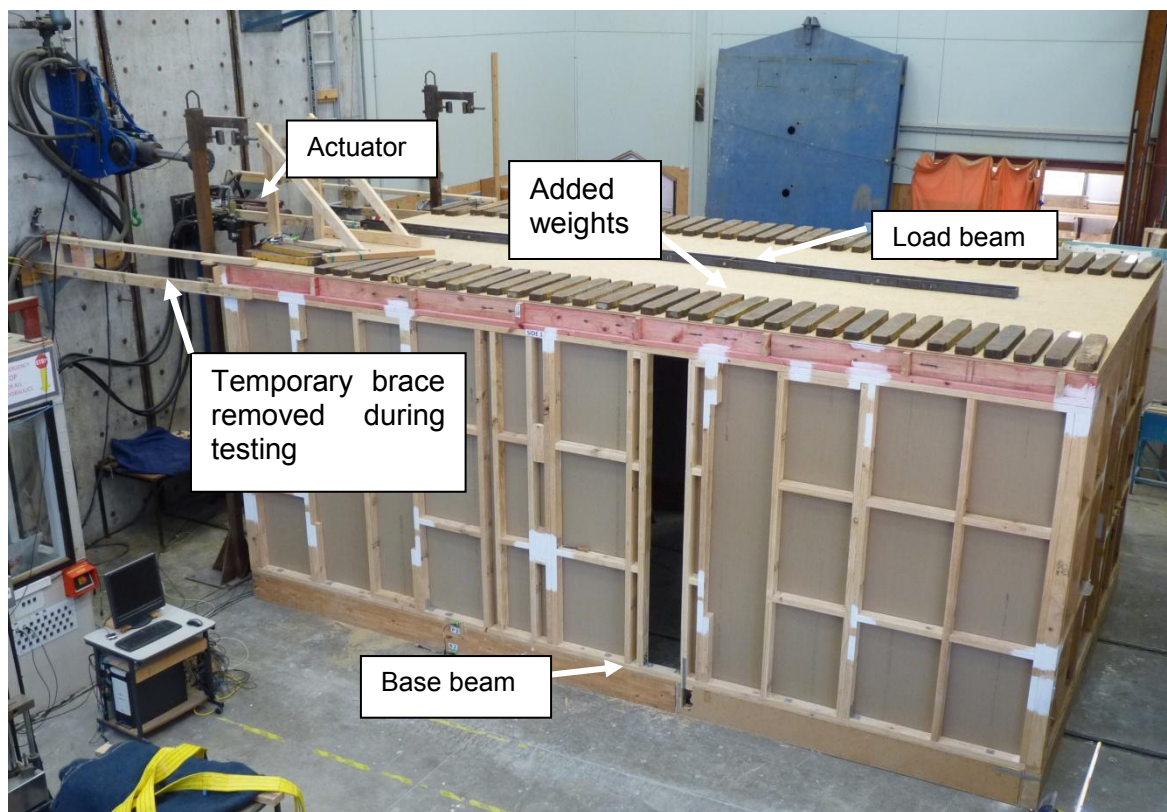


Figure 1. Photograph of test building

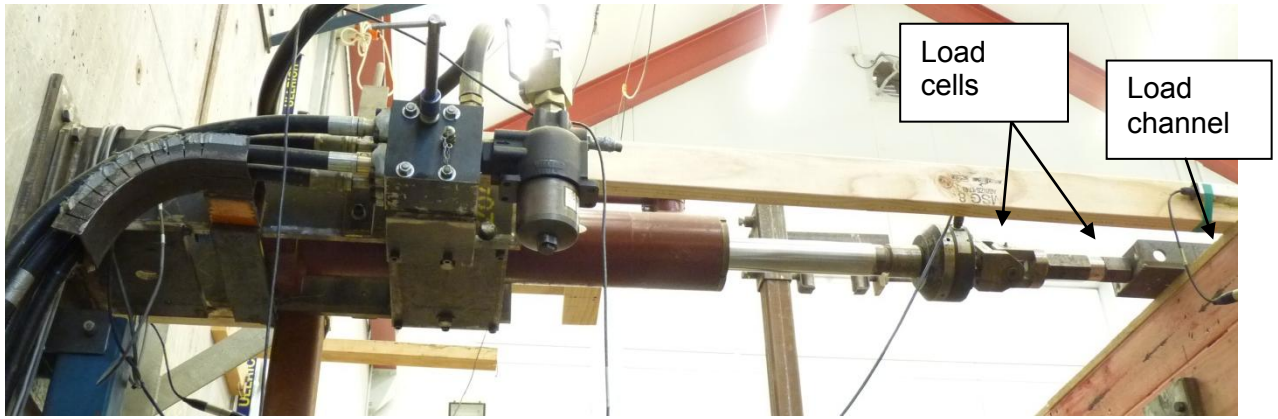


Figure 2. Actuator loading test building via load cells



Figure 3. Internal view of test room before testing commenced

5. TEST RESULTS

The hysteresis loops are shown in Figure 4 for deflections up to ± 24 mm and Figure 5 for all deflections.

To compare the test results from the test building with predictions from P21 tests on isolated bracing elements, bracing ratings of a typical plasterboard system of 70 BU's/m for wind and 60 BU's/m for earthquake were used. Thus, the predicted building wind bracing strength =

$(3.6+2.4) \times 2 \times 70 / 20 = 42$ kN and the predicted building earthquake bracing strength = $(3.6+2.4) \times 2 \times 60 / 20 = 36$ kN. These values are also shown in Figure 4 and Figure 5. Clearly, the building was significantly stronger than the sum of the component bracing panels.

The average of the positive and negative peak loads from the tests was 83.0 kN. Hence, the systems factor = $83.0 / 42 = 1.98$.

Peak loads achieved at ± 16.6 mm wall displacement did not deteriorate greatly during cycles to ± 23.0 mm wall displacement whereas the isolated 3.0 m long walls tested elsewhere [3] showed greater deterioration when cycled at ± 20 mm wall displacement. The subsequent load drop off was also more rapid in the tests [3].

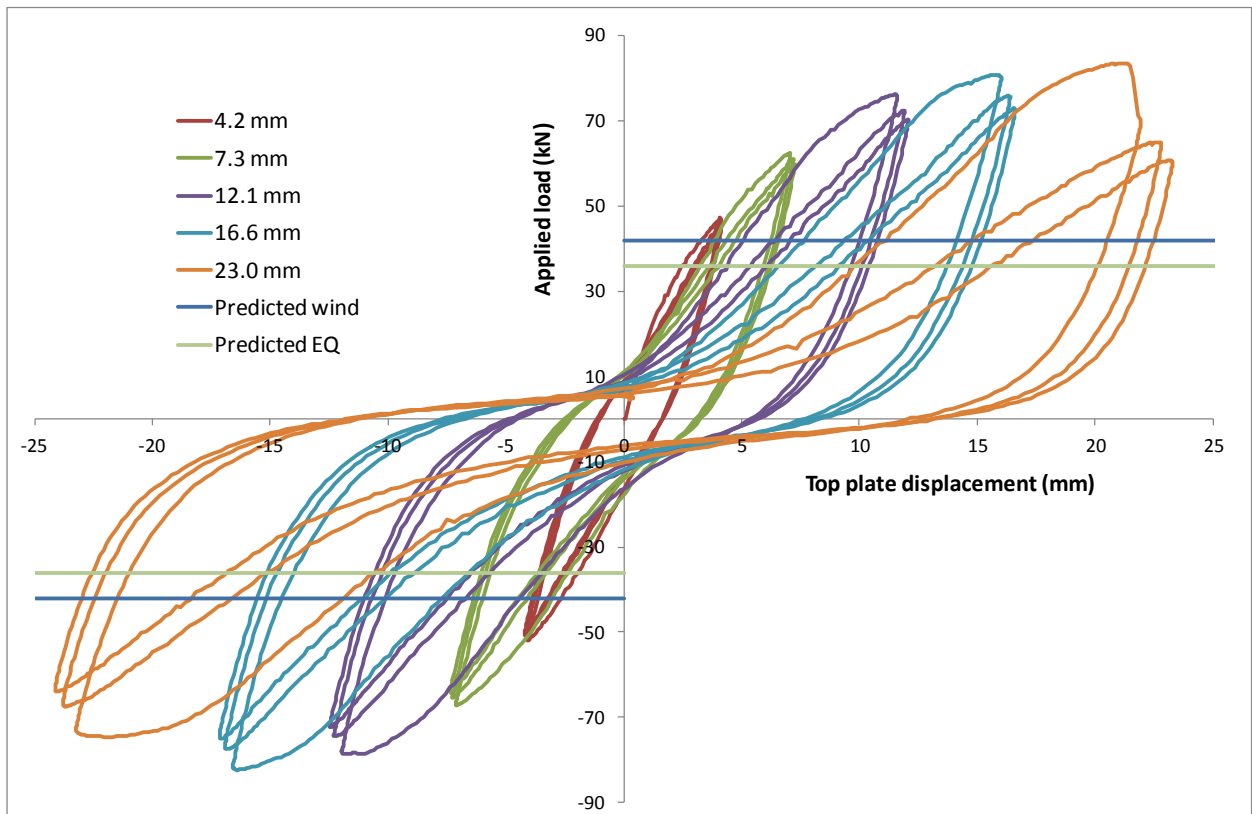


Figure 4. Hysteresis loops for wall displacements up to ± 23 mm

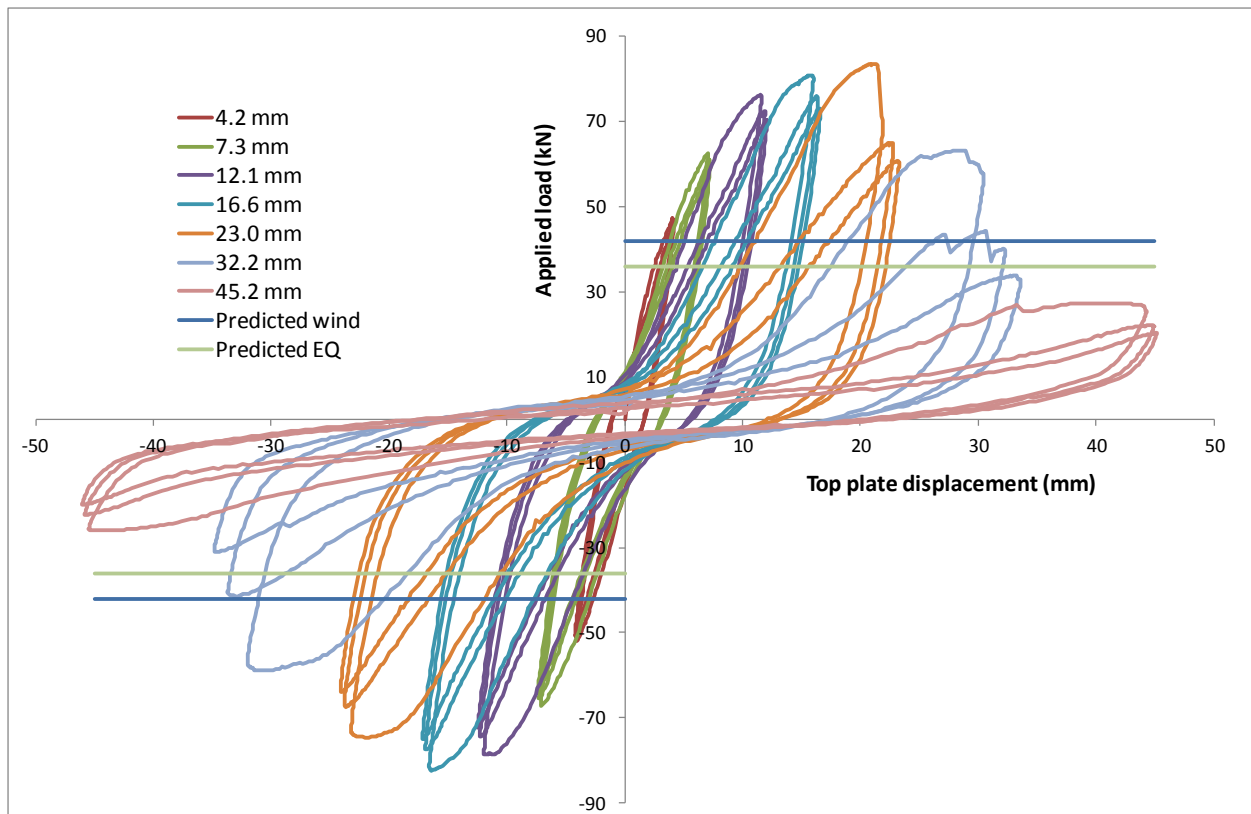


Figure 5. Hysteresis loops for all wall displacements

6. OBSERVATIONS

Photographs of damage observed in the test walls are presented in Appendix A. They are also shown in Figure 6 and described in Table 1. As the walls had skirting boards at the base and architraves on the vertical edges on the non-corner ends of bracing elements, damage at the fastener locations could not be observed until test completion, when these were removed.

No plasterboard cracks were observed in the cycling to ± 7.3 mm and damage was light and restricted to small cracks at the bottom of the non-corner ends of bracing panels in the cycling to ± 12.1 mm. At ± 16.6 mm, cracks also occurred at the corner ends of some walls.

At ± 23.0 mm, two vertical joints cracked at the sheet junctions in the 2.4 m long bracing panels and these became more severe and bowed off the wall during cycling to ± 32.2 mm.

After cycling to ± 45.2 mm, two sheets fell off the wall in the 3.6 m long bracing element of Side 2. After the skirting was removed it was noted that the sheet damage at screw locations along the base of the walls was very severe. Plasterboard damage was less, but still severe, at screw locations under the architraves on bracing panel ends which were not at wall corners. Some 300 mm long vertical cracks formed at the bottom of wall corners but generally damage at sheet corners was small and these joints largely remained intact. There was moderate damage at screw locations at the tops of the walls, being greater on Side 2 beneath the nailed scotia used on this side.

7. CONCLUSIONS

1. The test building did not degrade quite as fast as long P21 isolated test specimens.
2. The test building had a systems factor of approximately 2.0 which was mainly attributed to the plasterboard tape between orthogonal walls.

These two findings offer confidence that actual walls will provide at least as much effective house bracing as assumed in the P21 (2011) evaluation method.

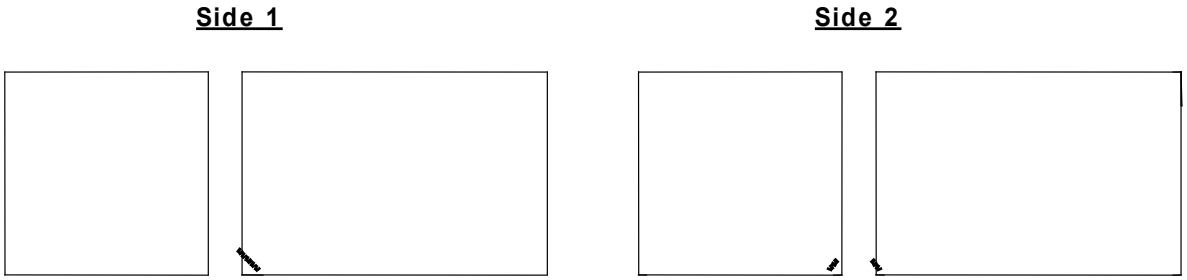
8. REFERENCES

- [1]. Shelton, RS. 2010. Technical paper P21 (2010) A wall bracing test and evaluation procedure. BRANZ technical report, Wellington, New Zealand.
- [2]. Thurston, SJ. 1995. Report on racking resistance of long sheathed timber framed walls with openings. BRANZ Study Report 54, Wellington, New Zealand.
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- [5]. Standards New Zealand. NZS 3604:2011. Timber framed buildings. SNZ, Wellington, New Zealand.
- [6]. Winstone Wallboards Ltd, 2010. GIB® site guide for residential and commercial installations.

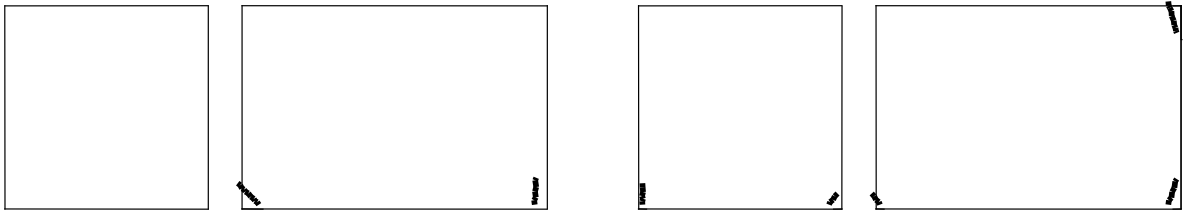
Table 1. Observed plasterboard damage

| Name | Wall displacement (mm) | Damage observed | Photographs in Appendix A |
|--------|------------------------|---|---------------------------|
| Long 1 | ±4.19 | None | None |
| Long 2 | ±7.32 | None | None |
| Long 3 | ±12.11 | Small diagonal cracks formed at the bottom of bracing elements at non-corner ends. | A.1, A.5 and A.6 |
| Long 4 | ±16.55 | Two further vertical cracks developed at the ends of bracing panels. | A.2, A.4 and A.8 |
| Long 5 | ±23.03 | Two vertical joints between sheets in the body of the bracing panels cracked. | A.3 and A.7 |
| Long 6 | ±32.17 | Three vertical joints had now cracked and the sheets bowed out free from the framing at these locations. | A.9 to A.12 |
| Long 7 | ±45.19 | Two sheets fell off the walls. The skirting, architraves and scotia were removed which revealed very severe damage at screw locations at the base of the walls, severe damage at bracing element ends which were not at corners, but no slip along joints or sheet damage at fastener locations at corners. There was moderate damage at screw locations at the tops of | A.13 and A.14 |

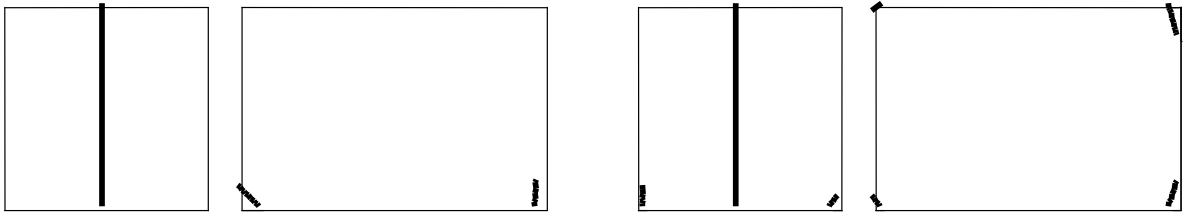
| | | |
|--|--|--|
| | walls on Side 1 but more severe damage at the tops of walls on Side 2. | |
|--|--|--|



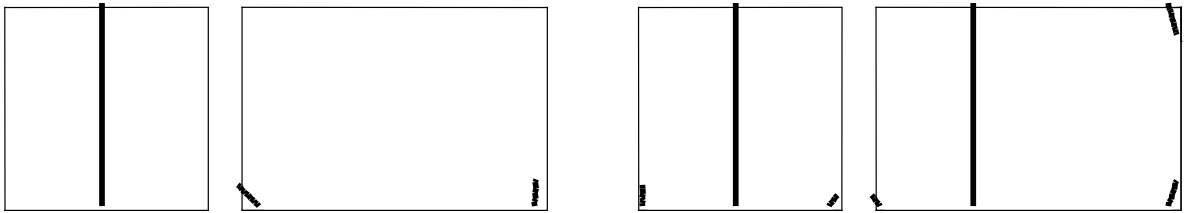
(a) After Regime Long 3 (Nominal 12 mm)



(b) After Regime Long 4 (Nominal 16.5 mm)



(c) After Regime Long 5 (Nominal 23 mm)



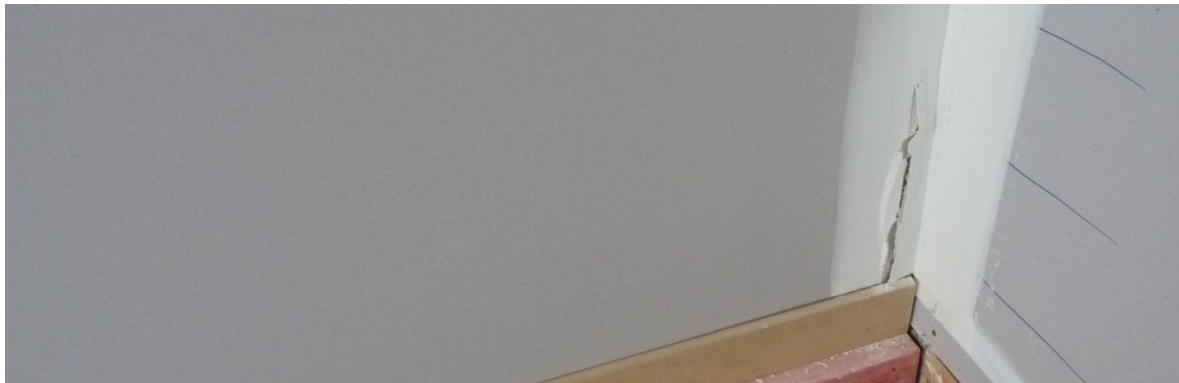
(d) After Regime Long 6 (Nominal 32 mm)

Figure 6. Plasterboard cracks observed during the tests

APPENDIX A PHOTOGRAPHS OF PLASTERBOARD DAMAGE



Photograph A.1. Plasterboard crack on the 3.6 m long wall on Side 1 formed after regime Long 3 (nominal 12 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.2. Plasterboard crack on the 3.6 m long wall on Side 1 formed after regime Long 4 (nominal 16 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.3. Plasterboard sheet joint crack on the 2.4 m long wall on Side 1 formed after regime Long 5 (nominal 23 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.4. Plasterboard crack on the 3.6 m long wall on Side 2 formed after regime Long 4 (nominal 16 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.5. Plasterboard crack on the 3.6 m long wall on Side 2 formed after regime Long 3 (nominal 12 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.6. Plasterboard crack on the 3.6 m long wall on Side 2 formed after regime Long 3 (nominal 12 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.7. Plasterboard crack on the 2.4 m long wall on Side 2 formed after regime Long 5 (nominal 23 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.8. Plasterboard crack on the 2.4 m long wall on Side 2 formed after regime Long 4 (nominal 16 mm) taken after regime Long 5 (nominal 23 mm)



Photograph A.9. Plasterboard crack on the 3.6 m long wall on Side 1 formed after regime Long 6 (nominal 32 mm) taken after regime Long 6 (nominal 32 mm)



Photograph A.10. Plasterboard joint tear on the 3.6 m long wall on Side 1 formed after regime Long 6 (nominal 32 mm) taken after regime Long 6 (nominal 32 mm)



Photograph A.11. Plasterboard joint tear on the 3.6 m long wall on Side 1 formed after regime Long 6 (nominal 32 mm) taken after regime Long 6 (nominal 32 mm)



Photograph A.12. Plasterboard joint tear on the 2.4 m long wall on Side 1 formed after regime Long 6 (nominal 32 mm) taken after regime Long 6 (nominal 32 mm)



Photograph A.13. Plasterboard sheet damage at the mid-length of the base of the 2.4 m long wall on Side 1 formed after regime Long 7 (nominal 45 mm). Note that the skirting has been removed to show damage to bottom sheet fixings



Photograph A.14. Plasterboard damage at the free end of the base of the 2.4 m long wall on Side 1 formed after regime Long 7 (nominal 45 mm)

APPENDIX B THEORY

From Eqn 5.2.9 of NZS 3603:1993 the racking deflection of a shear wall due to fastener slip = $2(1+a)me_n$ where a = wall aspect ratio. For a P21 test specimen where the plasterboard sheets go full wall height, $m = 1$.

At 12 mm wall racking deflection, Table 1 shows that the corner fasteners of long walls slip by approximately 4 mm, which is well past the peak load resisted by the fastener. Thus, long walls can be expected to have a more brittle performance.

Table 2. Slip of fasteners at corners of 2.4 m high bracing walls when wall racks 12 mm

| Wall length (m) | Value of $2(1+a)$ | Value of e_n (mm) at 12 mm wall racking |
|-----------------|-------------------|---|
| 0.6 | 10 | 1.2 |
| 1.2 | 6 | 2 |
| 2.4 | 4 | 3 |
| 3.6 | 3.33 | 3.6 |
| 4.8 | 3 | 4 |